Irrigation

{ir-i-gay'-shuhn}

Irrigation is the practice of artificially supplying water to land to sustain the growth of crops. An ancient agricultural technique, irrigation may have been practiced as early as 5000 BC along the banks of such regularly flooding rivers as the Nile, by digging channels to extend the area covered by the flood, and by erecting dikes to trap water on the land after the river had subsided. The development of diversion dams and of water-lifting machines permitted the irrigation of lands lying above those normally reached by floodwaters. Ancient remnants of these structures have been found in Egypt, Babylonia, China, Phoenicia, Peru, Mexico, India, and the United States. Modern irrigation systems are still based on these two key engineering innovations.

DIVERSION DAMS AND WATER-LIFTING MACHINES

The diversion dam supplies water from a stream to a canal system at an elevation above the lands to be irrigated. Often a reservoir for storage is included in the system. The canals follow the natural land contours, so that water flows by gravity to the fields.

Water-lifting machines were developed to lift water directly from streams or from canals to irrigate higher-lying fields. The shaduf in Egypt, and its counterpart in many other early agricultures, is simply a bucket and a counterweight attached to the ends of a pivoted pole. The bucket is pulled down, filled by hand, and then lifted by the counterweight. ARCHIMEDES' SCREW, a large hand-turned screw within a wooden cylinder, lifts water on its wide threads from the end dipped in the stream. The Persian wheel consists of a chain of buckets that pass over a vertical wheel and dip into the water. This vertical wheel is turned by a horizontal wheel rotated by a draft animal. The filled buckets are tipped into a trough or canal leading to the fields.

MODERN IRRIGATION SYSTEMS

Water distribution systems are of two broad types: surface and closed-conduit distribution systems.

Surface Irrigation

In surface irrigation systems, the entire land surface may be covered with water (flood irrigation), or the water may be restricted to small ditches called furrows or rills (furrow irrigation). Both flood and furrow irrigation are used on naturally sloping, ungraded fields, although the effectiveness of water absorption by the soil is improved if the fields are graded to a uniform slope. Recently the practice of dead-level surface irrigation--grading fields to a zero slope--has been introduced to improve irrigation uniformity. This practice requires a water stream large enough to cover the field or to fill the furrows in a time period that is short compared to the time required for the water to infiltrate the soil. Dead-level surface irrigation is presently limited to arid climates, where waterlogging of the soil is not a potential problem.

Closed-Conduit Irrigation

Closed-conduit irrigation systems use pipes to distribute water over wide areas or to the ground area around each plant. These systems can apply water uniformly, and they permit frequent light irrigations that maintain the desired level of moisture in the soil. Sprinkler systems distribute water by pumping it through a network of pipes that are either laid on the ground or lifted above the field; often the pipes are on wheels or other devices that permit the network to be moved from field to field. Bubbler irrigation supplies water through a small pipe that periodically delivers equal quantities to small basins at each plant or group of plants. Drip, or trickle, irrigation uses narrow plastic tubes that deliver small quantities of water frequently, but at an extremely slow rate, to the soil around the roots of each plant. This type of irrigation, widely used in the United States, Australia, and Israel, has had spectacular results. Drip systems use less water than other closed-circuit systems, supplying the precise amount needed to replace transpired plant moisture and the water that is evaporated from the soil. They also reduce the problem of soil salinity and create impressive crop yields.

PROBLEMS ASSOCIATED WITH IRRIGATION

Salt accumulation and waterlogging are the most severe problems caused by irrigation. Dissolved salts are present in small quantities in all irrigation water. As the water evaporates or is used by plants, the salt content of the water remaining in the soil increases. This remaining water may percolate down to the ground-water aquifer,

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which then becomes saltier. A few irrigated regions have sufficient natural drainage to prevent the water table from rising into the plant-root zone. But in many areas, the extra input to the aquifer as a result of percolation from irrigated fields and the seepage from unlined canals and reservoirs eventually exceeds the natural drainage capacity. Once the water table rises to within several feet of the surface the salty water moves to the ground surface by capillary action, and, as it evaporates, leaves behind a thin deposit of salt. Even if the aquifer itself does not become saline, the excess water in the root zone of the soil retards crop growth (see SALINIZATION).

Historically, salt accumulation and the waterlogging caused by inadequate drainage have taken a huge toll where agriculture has been based on irrigation. Mesopotamia's once-productive farmlands now bear some of the world's lowest crop yields because the crops grow on waterlogged, salty fields. The world's largest irrigation enterprise, the Indus Basin in Pakistan, is in serious danger as water tables rise to the surface and salt accumulates. More than one-third of the world's irrigated land (including some of the lush cropland in California's Imperial Valley) is being undermined by salinity.

If irrigated lands in semiarid regions are to remain permanently productive, two steps are necessary. Water tables must be kept at distances well below the surface, by reducing the seepage of irrigation water and by installing artificial drainage. Irrigation must also be managed so that a small additional increment of water passes through the soil around plant roots to leach salts below the root zone.

Stephen L. Rawlins

MAJOR IRRIGATION SYSTEMS OF THE WORLD

Irrigation is now practiced on every continent. The world total is approximately 250 million irrigated ha (618 million acres), which represents about 17% of all farmed lands. Some irrigation is necessary for most agricultures, and it is crucial for nations like Egypt, where all farmlands are irrigated. In addition, the production from irrigated agriculture supplies a far greater proportion of the world's food than its acreage represents. High-value crops such as vegetables, fruits, and nuts are often produced by irrigation, and the yield may be double the harvest from equally fertile but nonirrigated land. At present, five nations account for 63 percent of the world's total irrigated farmland: China, with the largest irrigated area; India; the United States; Pakistan; and the former USSR.

China

Irrigation has been practiced in China since at least the 3d century BC. The Tujiang Dam on the Min River, for example, which still supplies water to some 202,000 ha (500,000 acres), was constructed about 300 BC. In China, as in most Asian countries, the basic irrigation crop is rice, a semiaquatic plant that must be kept under flooded conditions during the growing season. In addition to rice, cotton and wheat are among the major irrigated crops. About two-thirds of China's arable land is now under irrigation.

Although many Chinese rivers are tapped for irrigation, the major rivers, the CHANG JIANG (Yangtze) and the HWANG HE, supply much of the country's irrigation water through a system of dams and reservoirs that also function as flood control units. The government of the People's Republic of China has been particularly active in bringing more land under irrigation, and the annual production in the Chang Jiang and Hwang He basins has doubled, and in some cases tripled, since 1949 as the result of an ambitious program of dam construction.

India

India has the second largest irrigation system in the world. The GANGES RIVER basin in northern India accounts for a number of large irrigation projects. Most of the rivers in northern India flow year-round; when they are swollen with melted snow from the Himalayas, they spill over their low banks into an extensive system of irrigation canals. Southern Indian rivers are high only during the monsoon season, and until recently, surface irrigation was limited mostly to the delta areas. Diversion dams that store the monsoon flow and canals to channel the water are being built, however.

In addition to river waters, much of India depends on well water for irrigation. At one time, most well irrigation used Persian wheels turned by bullocks to move the water from the wells to irrigation canals. Motor-driven pumps are rapidly replacing the Persian wheel, and since the 1960s, hundreds of thousands of driven, or tube, wells have been added to the irrigation system.

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Historically, salt accumulation and the waterlogging caused by inadequate drainage have taken a huge toll where agriculture has been based on irrigation. In Mesopotamia, once productive farmlands now bear some of the world's lowest crop yields because the soils are saline and waterlogged. The world's largest irrigation enterprise, the Indus Basin in Pakistan, is in serious danger as water tables rise to the surface and salt accumulates. More than one-third of the world's irrigated land, including some of the richest cropland in California's Imperial Valley, is being undermined by salinity.

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amount of land under irrigation has increased by more than 50 percent to over 44 million hectares (109 million acres) in the late 1980s.

The United States

Early irrigation, practiced by the Indians of the Southwest, consisted of digging wide furrows to carry water from streams to fields. Spanish settlers improved upon the method, extended irrigation to larger areas, and introduced the first dams and reservoirs into the New World.

Prior to the mid-19th century, however, most irrigation projects involved relatively small amounts of land. In 1847, Mormon settlers in Utah constructed a widespread system of irrigation canals and, by 1860, had placed more than 6,500 ha (16,000 acres) under irrigation. Other important 19th-century irrigation ventures included the more than 12,000 ha (30,000 acres) brought under irrigation by members of the Union Colony, a Colorado settlement established in 1870. The first U.S. government irrigation project was the construction (1868) of an irrigation system on the Mojave Indian reservation in Arizona. The building of irrigation projects in the western states flourished in the late 1800s. By 1900 nearly 3.6 million ha (9 million acres) were under irrigation.

Variations in rainfall divide the United States into a humid East and a relatively dry West. Except along the northern Pacific coasts and in the Rocky Mountains, the western half of the country has an average annual precipitation of less than 50.8 cm (20 in). Thus, irrigation is overwhelmingly concentrated in the western 17 states, which possess more than 90 percent of the total irrigated land. The U.S. Bureau of Reclamation, which has been responsible for several of the most important irrigation projects, operates only in the western states. The U.S. Army Corps of Engineers is also actively engaged in dam building and other irrigation construction.

The United States has more irrigated land than any other country in the Western Hemisphere--18.7 million ha (46.3 million acres), or about 5 percent of all U.S. farmland. Some 13 percent of all U.S. farms use some form of irrigation.

Pakistan

Nearly three-quarters of Pakistan's farmland is irrigated, and the prosperity of the country is dependent on the Indus River and its system of irrigation canals. These canals were built largely by the British during their control of the Indian subcontinent. Unfortunately, many of them were constructed without sufficient drainage, and soil waterlogging and salinization are increasing problems. Because of poor drainage, more than 10 percent of Pakistan's farmland has gone out of production.

The Former USSR

Although only a small percentage of USSR farmland was irrigated, the country at one time ranked fifth in the world in the total area under irrigation. Most of the irrigation projects were located in Caucasia and Central Asia. Under the Virgin Lands program in the 1950s and early '60s, large areas of semiarid land were brought under irrigation.

The Middle East

Wide-scale irrigation is practiced in many of the more arid Middle Eastern countries, especially along the Nile and the Tigris-Euphrates rivers, and in Israel. The Middle Eastern countries with the largest irrigated land areas are Iran, Egypt, Turkey, and Iraq. Egypt's irrigation system is the oldest in the world. Modern irrigation projects in Egypt on the NILE RIVER include the ASWAN HIGH DAM and the Asyut Barrage. The Nile and its two main tributaries, the White Nile and the Blue Nile, are also used to irrigate large tracts of cropland in Sudan.

In Israel about 65 percent of the land under cultivation is irrigated. The major irrigation development, the National Water Carrier, channels surplus water from the Sea of Galilee south to the Negev Desert through a system of pipelines and canals. The Israelis have pioneered in the search for new water sources--from the sea, through desalination projects, and from the air, through new dew-trapping techniques--and they have made better use of existing water supplies, especially through drip irrigation.

Political and Economic Impact

As irrigation systems increase in size and number certain intractable problems have emerged. Principally, population pressures will eventually force the transfer of limited water supplies from crops to people--as experts

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anticipate will happen in Egypt in the near future. More immediate problems include those created by large-scale water diversion. For decades the USSR diverted much of the water entering the Aral Sea for cotton-field irrigation. The sea has shrunk by 40 percent in area, causing ecological and economic ills of major proportions. In the Middle East large water-shifting schemes, such as Turkey's Tigris and Euphrates River projects, have been built on rivers that cross national frontiers, reducing water supplies to farmers and populations in the countries downstream. The world's longest irrigation canal, the Rajasthan/Indira Gandhi Canal in northwestern India, has transformed millions of acres of barren desert into productive cropland; but the transfer of huge amounts of water from Punjab to the canal has added to the grievances of the Punjabi Sikhs against the central government.

Proposed solutions all involve attempts to conserve irrigation water: reducing government subsidies on irrigation water and raising its price; lowering water-loss rates by upgrading--adding cement linings to canals, for example, and reducing evaporation by using new methods such as drip irrigation.

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